Journal of Biomedical Informatics 46 (2013) 977–984

Contents lists available at SciVerse ScienceDirect

Journal of Biomedical Informatics

journal homepage: www.elsevier.com/locate/yjbin

# Sharing clinical decisions for multimorbidity case management using social network and open-source tools

Alicia Martínez-García [a], Alberto Moreno-Conde [a], Francisco Jódar-Sánchez [a], Sandra Leal [b], Carlos Parra [a,*]

[a] Technological Innovation Group, Virgen del Rocío University Hospital, Manuel Siurot Avenue, s/n, 41013 Seville, Spain
[b] Research, Development and Innovation Department, Virgen del Rocío University Hospital, Manuel Siurot Avenue, s/n, 41013 Seville, Spain

ARTICLE INFO

*Article history:*
Received 18 October 2012
Accepted 13 June 2013
Available online 25 June 2013

*Keywords:*
Decision support systems
Clinical
Social network
Multimorbidity patient
Case management
Technology acceptance model

ABSTRACT

*Introduction:* Social networks applied through Web 2.0 tools have gained importance in health domain, because they produce improvements on the communication and coordination capabilities among health professionals. This is highly relevant for multimorbidity patients care because there is a large number of health professionals in charge of patient care, and this requires to obtain clinical consensus in their decisions. Our objective is to develop a tool for collaborative work among health professionals for multimorbidity patient care. We describe the architecture to incorporate decision support functionalities in a social network tool to enable the adoption of shared decisions among health professionals from different care levels. As part of the first stage of the project, this paper describes the results obtained in a pilot study about acceptance and use of the social network component in our healthcare setting.
*Methods:* At Virgen del Rocío University Hospital we have designed and developed the Shared Care Platform (SCP) to provide support in the continuity of care for multimorbidity patients. The SCP has two consecutively developed components: social network component, called Clinical Wall, and Clinical Decision Support (CDS) system. The Clinical Wall contains a record where health professionals are able to debate and define shared decisions. We conducted a pilot study to assess the use and acceptance of the SCP by healthcare professionals through questionnaire based on the theory of the Technology Acceptance Model.
*Results:* In March 2012 we released and deployed the SCP, but only with the social network component. The pilot project lasted 6 months in the hospital and 2 primary care centers. From March to September 2012 we created 16 records in the Clinical Wall, all with a high priority. A total of 10 professionals took part in the exchange of messages: 3 internists and 7 general practitioners generated 33 messages. 12 of the 16 record (75%) were answered by the destination health professionals. The professionals valued positively all the items in the questionnaire. As part of the SCP, opensource tools for CDS will be incorporated to provide recommendations for medication and problem interactions, as well as to calculate indexes or scales from validated questionnaires. They will receive the patient summary information provided by the regional Electronic Health Record system through a web service with the information defined according to the virtual Medical Record specification.
*Conclusions:* Clinical Wall has been developed to allow communication and coordination between the healthcare professionals involved in multimorbidity patient care. Agreed decisions were about coordination for appointment changing, patient conditions, diagnosis tests, and prescription changes and renewal. The application of interoperability standards and open source software can bridge the gap between

*Abbreviations:* CDS, clinical decision support; VRUH, Virgen del Rocío University Hospital; SCP, shared care platform; GP, general practitioner; TAM, technology acceptance model; IU, intention to use; PU, perceived usefulness; PEU, perceived ease of use; SN, subjective norm; FC, facilitating conditions; LPPC, las palmeritas primary care; CPC, camas primary care; SD, standard deviation; DSS, decision support service; STOPP, screening tool of older peoples prescriptions; START, screening tool to alert doctors to right treatment; vMR, virtual medical record; ESB, enterprise service bus; EHR, electronic health record; SOA, service oriented architecture; UDB, user data base; COAM, centralized operator access module; CCD, centralized clinical data; CSS, cascading style sheets; JSF, java served faces; LOPD, protection of patient data; ICD-9, international classifications of disease 9; ATC, anatomical therapeutic chemical.

* Corresponding author. Fax: +34 955013310.
*E-mail address:* carlos.parra.sspa@juntadeandalucia.es (C. Parra).

1532-0464/$ - see front matter 
http://dx.doi.org/10.1016/j.jbi.2013.06.007

knowledge and clinical practice, while enabling interoperability and scalability. Open source with the social network encourages adoption and facilitates collaboration. Although the results obtained for use indicators are still not as high as it was expected, based on the promising results obtained in the acceptance questionnaire of SMP, we expect that the new CDS tools will increase the use by the health professionals.



## 1. Introduction

Social networks applied through Web 2.0 tools have gained importance in health domain [1], because they produce improvements on the communication and coordination capabilities among health professionals. The previous experiences identified about the application of social networks and Web 2.0 tools for the management of illnesses have focused on the improvement in medical professional–patient communication or self-management of illnesses by patients. These experiences identified benefits for patient healthcare [2,3], and aspects to improve usability, privacy and encouragement of use [4,5].

These tools may be complemented with Clinical Decision Support (CDS) utilities, designed to help clinical professionals in the decision-making process, improving the quality and security of healthcare [6–8]. Although decision support tools are recognized as key instruments for improving patient safety and facilitating the adherence to recommended clinical practice, their adoption is not generalized in health information systems.

This article presents the development of a Web 2.0 tool which facilitates healthcare professionals' treatment and care of multimorbidity patients. These patients are defined as having two or more chronic illnesses from a series of clinical categories, which generate a progressive deterioration and gradual loss of autonomy, combined with the risk of suffering different interrelated pathologies.

The World Health Organization forecasts that the percentage of deaths from the main chronic illnesses in the world will increase in the period between 2004 and 2030 from 12.2% to 14.2% for ischemic cardiopathology; from 9.7% to 12.1% for cerebrovascular disease; from 5.1% to 8.6% for chronic obstructive pulmonary disease; from 1.9% to 3.3% for diabetes mellitus and from 1.7% to 2.21% for hypertensive cardiopathology [9].

Previous studies have demonstrated the characteristics and complexity of these patients [10–12] and provide a solid argument for the development of a tool to support shared care between the different healthcare levels that these patients need. In Virgen del Rocío University Hospital (VRUH), the Internal Medicine Department coordinates the continuity of care for multimorbidity patients since 1992, with an integrated care model that specifies who is the internist and nurse in the hospital responsible for continuity of care for each primary care center and establishes a periodic assessment plan for multimorbidity patients to make possible to determine the evolution in cognitive, functional and health status of these patient. This model has was supported previously only by telephone conversations and face-to-face meetings [13].

Our objective is to develop a tool for collaborative work among health professionals for multimorbidity patient care. We describe the architecture to incorporate decision support functionalities in a social network tool to enable the adoption of shared decisions among health professionals from different care levels. As part of the first stage of the project, this paper describes the results obtained in a pilot study about acceptance and use of the social network component in our healthcare setting.

## 2. Materials and methods

At VRUH we have designed and developed the Shared Care Platform (SCP) to provide support in the continuity of care for multimorbidity patients.

### 2.1. Platform design

The SCP has two consecutively developed components.

#### 2.1.1. Social network component: Clinical Wall

The SCP has been developed to allow communication and coordination between the healthcare professionals involved in multimorbidity patient care. The first available component has been designed to support the work at different healthcare levels, such as Primary, Specialized and Home Care, which are involved in the care of multimorbidity patients.

The SCP has an option for generating records to support the dialog between professionals using social network technologies. We have called it the Clinical Wall due to its similarities with conversations in the wall of a social network website. When two or more professionals need to discuss a patient's care, they can start a conversation in the Clinical Wall. This component makes it possible for healthcare professionals responsible for a patient's care to exchange messages, until they agree on conclusions or final decisions. If the healthcare professionals taking part in the Clinical Wall decide that the opinion of another colleague is required, they can invite these experts to join the conversation and contribute with their clinical expertise. These conversations are linked to the patient's record as additional information to support changes in the treatment plan or care showing on the left side of the screen a tree of folders containing all the documents related to the patient. The record is composed from the following sections:

- Patient assessment section: In this section any healthcare professional starts the dialog with a clinical question (clinical sender). This question will be accompanied with additional information such as patient evolution, examination, complementary tests, treatment plan and current clinical assessment, to provide an exhaustive patient clinical context for colleagues. The question will be directed towards one specialist whose expertise is related with the information required (clinical receptor). In addition, the set of actors involved in the continuity of care process defined for multimorbidity patients are: General Practitioner (GP), primary care nurse, internist and Hospital nurse. Automatically, they will be included in the conversation in order to let them add relevant information, if required.
- Discussion section: This section acts like a forum where the previously included health professionals will be able to provide the information and arguments to make a decision.
- Conclusions section: Once clinical question sender and receptor agree on their conclusions and future actions for patient care they have to sign it as a shared decision.

It is required that both professionals sign the conclusion to be able to close the conversation in order to ensure that they will be responsible of the outcomes derived from changes in treatment plan, new appointment for hospital or GP encounter, schedule for additional tests.

*2.1.1.1. Pilot study design.* We conducted a pilot study to assess the use and acceptance of the SCP by healthcare professionals.

In relation to usage variables, we analyzed the number and type of record in the Clinical Wall, the total number of messages exchanged and the number of healthcare professionals who took part. We also defined as main usage indicators the percentage of messages answered and the percentage of records in the Clinical Wall ending in agreements between professionals (signed jointly).

To assess the acceptance of the SCP by the healthcare professionals we prepared a questionnaire based on the theory of the Technology Acceptance Model (TAM) [14]. The items used in the questionnaire were taken from the literature [15] and validated by a panel of experts in healthcare technology assessment. The aim of this questionnaire was to analyze the Intention to use (IU) the SCP. The questionnaire has 21 items on the following dimensions: Perceived usefulness (PU), Perceived ease of use (PEU), Subjective norm (SN), Facilitating conditions (FCs) and IU (Table 1). The items were ordered randomly and the professionals were asked to score each item between 1 and 10, with 1 meaning 'totally disagree' and 10 'totally agree'. The questionnaire was sent by email to 70 professionals from three healthcare centers: Las Palmeritas Primary Care (LPPC), Camas Primary Care (CPC) and VRUH.

We conducted a descriptive analysis for the questionnaire items, expressing the result as mean ± Standard deviation (SD). To test the reliability of the questionnaire we performed an internal consistency analysis using Cronbach's alpha.

Finally, we conducted a correlation analysis of the IU variable, the dependent variable, and the four independent variables of the questionnaire (PU, PEU, SN and FC) and an analysis of the variance of the differences in the IU variables between the professional groups and healthcare centers.

*2.1.2. CDS System*

The combination of Decision Support Services (DSSs) and social network capabilities allows clinicians to obtain and share recommendations provided by the system.

Using the SCP, a social network based component that facilitates shared work, we considered introducing a DSS to back up professionals, allowing them to share the results of CDS that our system provides them, enabling them to benefit from the reasoning of other professionals.

Decision support functionalities are designed to provide support in the following tasks, ensuring that all the actors involved in multimorbidity patient care have a common recommendation:

- Collaborative work when completing indexes and scales. Professionals working on the care of multimorbidity patients need to use indexes and scales, such as the PROFUND Index [16], to stratify patients according to their risk.
- We have drawn up a set of recommendations based on the interaction between the large number of problems patients have and the wide range of medications they are prescribed to increase their overall safety. This helps identify possible interactions between prescriptions and health problems and shares problems and resulting alerts. This service works on the clinical data from the regional primary care history. The definition of the rules has been based on:
  - Medication lists, problems, allergies, etc.
  - Contraindications, precautions, interactions, adverse effects, medications reports, dosage according to indications, Beers criteria [17–19], Screening Tool of Older Peoples Prescriptions (STOPPs) and Screening Tool to Alert doctors to Right Treatment (START) criteria [20].

To promote the standardization of platform communication, the decision support scenarios are based on the work done within the HL7 CDS working group. This is obtained using OpenCDS as the execution rules engine. OpenCDS is an opensource tool [21] that defines a reference implementation of the standard HL7/OMG DSS interface. This standard provides a DSS specification that facilitates the implementation of CDS. OpenCDS also satisfies the use of Virtual Medical Record (vMR) reference model [22] and JBoss Drools Guvnor tool to define the rules [23].

DSS standards specify a standard interface for providing CDS as a software service, and this is part of a larger effort to standardize software service interfaces for healthcare known as the HL7-OMG healthcare services specification.

**Table 1**
Items in the acceptance questionnaire.

| Dimension | Item |
|---|---|
| PU1 | The SCP would give me greater coordination with other professionals |
| PU2 | The SCP could support critical aspects in the care and treatment of my patients |
| PU3 | The SCP could improve my performance at work |
| PU4 | The SCP could help me resolve some clinical decisions more quickly |
| PU5 | The SCP could improve the healthcare of my patients |
| PU6 | In general, the SCP may help to improve communication with other professionals |
| PEU1 | I think I would find it easy to learn to use the SCP |
| PEU2 | I think the dialog carried out in the SCP would be clear |
| PEU3 | I think it would be easy to acquire the skills required to use the SCP |
| PEU4 | In general, I think the SCP will be easy to use |
| SN1 | My colleagues in my specialty would approve of me using the SCP |
| SN2 | My superiors would approve of me using the SCP |
| SN3 | Other healthcare professionals would approve of me using the SCP |
| SN4 | In general, I think that my healthcare center would support the use of the SCP |
| FC1 | I think I will have the technical support to sort out problems related to the SCP |
| FC2 | I think I will have the resources I need to use the SCP |
| FC3 | I think the SCP will be compatible with other systems I use |
| FC4 | I think my center has the infrastructure necessary for me to use the SCP |
| IU1 | I intend to use the SCP when it is available at my center |
| IU2 | I intend to create a dialog sheet in the SCP when I want to establish communication with other professionals |
| IU3 | I intend to take part in the Clinical Wall when other professionals wish to communicate with me |

*2.1.3. Integration with the regional infrastructure*

The Andalusian regional infrastructure is homogeneous for all hospitals, while departments can integrate specialized systems to satisfy their local needs. A set of Enterprise Service Buses (ESBs) are deployed in each infrastructure node to create a bus connecting all the region's Electronic Health Record (EHR) systems with the central node.

The SCP is integrated within the Service oriented architecture (SOA) regional architecture as a departmental system allowing the use of services offered by the central node and without affecting the EHR systems used in clinical practice. Due to its homogeneous regional architecture, the platform has been designed so that it can be replicated in any other hospital in the region or even be deployed in the central node of the regional infrastructure as a new service available for the different care levels.

The integration with the SOA bus defined by the Andalusian Health Service has been done by the Ensemble platform. The SCP has been designed to be interoperable with the following services deployed in the central node of the regional infrastructure:

- User Data Base (UDB). This is a centralized patient ID management system. A unique identifier, called the NUHSA, has been assigned to all patients in our region.
- Centralized Operator Access Module (COAM). This system manages professional roles and passwords to allow other applications to set different access levels.
- Centralized Clinical Data (CCD). This system is a registry that contains identifiers and pointers to the clinical reports. Furthermore, it stores information about encounters, allergies, problems and treatments, etc.

*2.1.4. Communications with the DSS engine*

The information provided by the regional service is the source for our DSS. To make this possible, the information received from the CCD external system complies with the format defined by version 2.X of the HL7 standard. To use OpenCDS and vMR, we need to change the original format, to obtain the same information with the vMR format which is the specification that OpenCDS has defined as source data for rule execution.

To map the data between reference models, we have used the LinkEHR-Ed tool [24]. This tool allows mapping from legacy data to the most commons reference models or specifications applied for EHR communication. The application requires defining the resultant output format of the transformation. Once the output format is defined, an XQuery transformation file can be generated. This file executed by our ESB to do transformations in real time of the documents to conform with the vMR specifications.

*2.2. Platform implementation*

The SCP has been developed with an architecture has been designed according to the SOA to promote system flexibility. It is compliant with the Model–View–Controller pattern.

- Presentation layer is based on XHTML, Cascading Style Sheets (CSSs) and JavaScript. In order to obtain separation between presentation and behavior, SCP incorporates the ICEfaces framework which based on Java Served Faces (JSFs) standard.
- Persistence layer based on Hibernate tools to optimize maintenance, performance and flexibility of databases.

SCP Authentication is based on Active Directory where different access levels are defined for each role with encrypted passwords that are updated every 3 months. The SCP is deployed in the Andalusian Health Service regional network which is certified as a safe network. In addition, this project has been approved by the VRUH ethical committee and the SCP has been designed to satisfy the Spanish Laws on data protection, patient autonomy and right as well as keeping the statistical secret:

- The Organic Law 15/1999 of December 13 of Protection of Patient Data (LOPD). The platform ensures that information is transmitted and in it is stored in a secure way to meet this law.
- Similarly, the Organic Law of Public Statistical Function (BOE 112, 15/5/1989) states the obligation of "statistical secret".
- The Law 41/2002 released on November the 14th, regulatory of the patient autonomy and rights and duties as regards of clinical information.

## 3. Results

The development phase was divided into two stages. We achieved the aim of the first phase, creating a component to allow communication and coordination between professionals based on social networks. The aim of the second phase was to enhance the Clinical Wall by providing the sharing component with CDS utilities.

In March 2012 we released and deployed the SCP, but only with the social network component. The pilot project lasted 6 months in the hospital and 2 primary care centers. This resulted in 70 registered users from different specialties.

*3.1. Evaluation of pilot stage: Clinical Wall*

From March to September 2012 we created 16 records in the Clinical Wall, all with a high priority. A total of 10 professionals took part in the exchange of messages: 3 internists and 7 GPs generated 33 messages. 12 of the 16 records (75%) were answered by the destination health professionals. Table 2 shows a classification about the kind of agreed decisions taken between professionals using the SCP, they were related to complex patients who have two or more of the diseases including: Heart failure, Ischemic heart

**Table 2**
Agreed decisions between health professionals.

| Agreed decisions | % |
|---|---|
| Coordination for changes in appointments | 50 |
| Diagnosis tests and patients' conditions | 25 |
| Prescription changes and renewal | 25 |

**Table 3**
Characteristics of medical professionals who have used SCP.

| Variable | Categories | *n* (%) |
|---|---|---|
| Sex | Females | 29 (72.5) |
| | Males | 11 (27.5) |
| Age | 30–39 | 4 (10.0) |
| | 40–49 | 12 (30.0) |
| | 50–59 | 20 (50.0) |
| | ⩾60 | 4 (10.0) |
| Medical specialty[a] | Nurses | 16 (40.0) |
| | GPs | 17 (42.5) |
| | Internists | 6 (15.0) |
| Center | LPPC | 16 (40.0) |
| | CPC | 11 (27.5) |
| | VRUH | 13 (32.5) |
| Clinical practice year[a] | <9 | 2 (5.0) |
| | 10–19 | 7 (17.5) |
| | 20–29 | 16 (40.0) |
| | 30–39 | 12 (30.0) |
| | ⩾40 | 1 (2.5) |

[a] Some values are missing for these variables. Data are presented as *n* (%).

**Table 4**
Descriptive statistics of the SCP questionnaire items.

| Item | LPPC | CPC | VRUH | Total |
|---|---|---|---|---|
| PU | 6.78 ± 1.69 | 8.01 ± 0.86 | 8.09 ± 1.46 | 7.54 ± 1.53 |
| PU1 | 6.94 ± 1.61 | 8.64 ± 0.92 | 8.38 ± 1.61 | 7.88 ± 1.62 |
| PU2 | 6.88 ± 1.86 | 8.18 ± 1.08 | 8.31 ± 1.32 | 7.70 ± 1.62 |
| PU3 | 6.13 ± 1.99 | 7.36 ± 1.69 | 7.62 ± 2.14 | 6.97 ± 2.03 |
| PU4 | 6.80 ± 1.97 | 7.36 ± 2.25 | 7.54 ± 1.94 | 7.21 ± 2.01 |
| PU5 | 6.93 ± 1.91 | 7.73 ± 0.90 | 8.15 ± 1.91 | 7.56 ± 1.73 |
| PU6 | 7.19 ± 1.83 | 8.82 ± 0.98 | 8.54 ± 1.20 | 8.08 ± 1.59 |
| PEU | 6.03 ± 1.76 | 7.64 ± 0.94 | 7.90 ± 1.29 | 7.08 ± 1.64 |
| PEU1 | 5.81 ± 2.10 | 7.73 ± 1.49 | 7.92 ± 1.44 | 7.03 ± 1.98 |
| PEU2 | 6.38 ± 1.86 | 7.73 ± 1.35 | 7.54 ± 1.39 | 7.13 ± 1.67 |
| PEU3 | 6.20 ± 1.97 | 7.91 ± 1.45 | 8.23 ± 1.30 | 7.36 ± 1.84 |
| PEU4 | 5.81 ± 2.07 | 7.18 ± 1.25 | 7.92 ± 1.32 | 6.88 ± 1.86 |
| SN | 6.86 ± 1.26 | 8.57 ± 0.72 | 8.13 ± 1.28 | 7.74 ± 1.35 |
| SN1 | 6.50 ± 1.51 | 8.27 ± 1.42 | 7.62 ± 1.61 | 7.35 ± 1.66 |
| SN2 | 7.47 ± 1.77 | 9.45 ± 0.93 | 9.08 ± 1.11 | 8.56 ± 1.60 |
| SN3 | 6.38 ± 1.59 | 7.82 ± 1.40 | 7.85 ± 1.68 | 7.25 ± 1.69 |
| SN4 | 7.27 ± 1.53 | 8.73 ± 1.01 | 8.00 ± 1.29 | 7.92 ± 1.42 |
| FC | 6.04 ± 1.56 | 7.16 ± 1.65 | 7.60 ± 1.42 | 6.85 ± 1.66 |
| FC1 | 5.63 ± 1.75 | 6.27 ± 2.87 | 7.46 ± 1.66 | 6.40 ± 2.18 |
| FC2 | 5.88 ± 1.54 | 6.55 ± 2.21 | 7.62 ± 1.66 | 6.63 ± 1.89 |
| FC3 | 6.31 ± 1.85 | 7.82 ± 1.72 | 7.54 ± 1.45 | 7.13 ± 1.79 |
| FC4 | 6.47 ± 2.07 | 8.00 ± 1.34 | 7.77 ± 1.48 | 7.33 ± 1.80 |
| IU | 6.83 ± 1.70 | 8.30 ± 1.07 | 8.77 ± 1.12 | 7.87 ± 1.60 |
| IU1 | 7.00 ± 1.63 | 8.55 ± 1.51 | 8.85 ± 1.07 | 8.03 ± 1.64 |
| IU2 | 6.80 ± 1.61 | 8.00 ± 1.18 | 8.62 ± 1.39 | 7.74 ± 1.60 |
| IU3 | 6.81 ± 2.04 | 8.36 ± 1.03 | 8.85 ± 1.21 | 7.90 ± 1.78 |

Data are presented as mean ± SD.

disease, Chronic liver disease, COPD, Chronic Renal Diseases and other chronic diseases (these are the inclusion criteria for the multimorbidity patients integrated care process).

In total, we sent out 70 questionnaires, of which we received 40 (57%) completed. Table 3 summarizes the main characteristics of the medical professionals who completed the questionnaire about acceptance of SCP.

Table 4 shows the descriptive statistics analysis of the items questionnaire. The professionals valued positively all the items in the questionnaire, with mean values of over 5 points. Grouping items into dimensions, high mean scores were obtained: 7.54 (SD 1.53) for PU, 7.08 (SD 1.64) for PEU, 7.74 (SD 1.35) for SN, 6.85 (SD 1.66) for FC and 7.87 (SD 1.60) for IU. The analysis of internal consistency for the whole questionnaire gave a Cronbach's alpha of 0.967, higher than the recommended value of 0.7.

We analyzed the correlation of the IU variable, the dependent variable, and the four independent variables of the questionnaire (PU, PEU, SN and FC). Before performing the analysis, we performed the normality tests of Kolmogorov–Smirnov and Shapiro–Wilk for the mean variables for each of the study variables. We found that the variables analyzed did not follow a normal distribution; we therefore calculated the non-parametric correlation coefficients of Spearman: 0.747($p < 0.01$) for PU, 0.796($p < 0.01$) for PEU, 0.701($p < 0.01$) with SN and 0.608($p < 0.01$) with FC.

We also analyzed the differences in the IU variable between the professional groups and healthcare centers through the variance analysis of one factor. We did not encounter significant differences ($p = 0.265$) in the assessment of the IU variable between the professional groups: 7.77 (SD 1.74) in the nurses, 7.69 (SD 1.57) in the GPs and 8.89 (SD 1.02) in the internists. However, we did find significant differences ($p = 0.001$) among the healthcare centers: 6.83 (SD 1.70) at LPPC, 8.30 (SD 1.07) at CPC and 8.77 (SD 1.12) at VRUH.

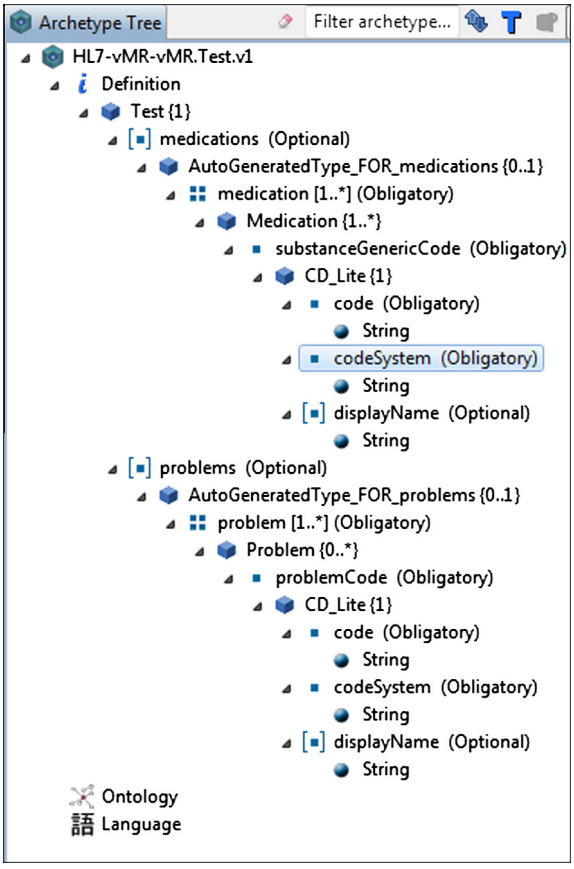


**Fig. 2.** Medications and problems output scheme using the vMR reference model.

### 3.2. The SCP

In this platform in addition to the Clinical Wall linked to the EHR system, OpenCDS has been integrated through a web service with the information defined according to the vMR specification. This web service evaluates the information according to the corresponding rule previously defined with JBoss Drools Guvnor tool. The web service response includes the result of the rule evaluation that will be sent to the presentation layer to show clinicians the recommended decision within the Clinical Wall. Fig. 1 shows the SCP architecture.

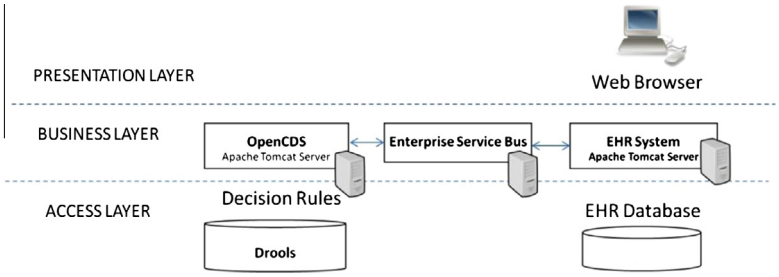


**Fig. 1.** SCP architecture.

To use OpenCDS and vMR, we needed to map the original data model provided by the regional CCD service onto the current data model, in other words, we had to convert CCD format to vMR format, using LinkEHR-ed.

As an example, we are going to present the transformation process for the items which represent problems and prescriptions, a step required to enable the second, above- mentioned component. We should point out that we verified the compatibility of the data model used by our information systems and vMR, and so far we have not encountered any problems identifying items in the origin and destination reference models.

To transform the information from CCD format to vMR, first of all, we needed to define the output scheme of the necessary items (in this case, problems and prescriptions), following the destination reference model, in this case vMR. Fig. 2 shows the output scheme.

Once we had constructed the medications and problems output scheme, using the message received from CCD as the data source, we specified the correspondence between each of the items that we needed. When we had specified the mapping, we generated the xQuery file. Fig. 3 shows a fragment of this file.

Using xQuery file, and thanks to an xQuery's motor such as Saxon, we were able to give the ESB the intelligence required to translate CCD information to vMR format.

Having converted the information into a vMR format, we were able to invoke a rule created with Guvnor, using OpenCDS. Here is an example of the rule: As an example, Figs. 4 and 5 shows one of the rules included in the START criteria for the cardiovascular system, which recommends the use of Warfarin in the presence of chronic atrial fibrillation. Fig. 4 shows the rule in Guvnor interface, and Fig. 5 shows the same rule in text format. This rule has been defined with the Guvnor tool using the International Classifications of Disease 9 (ICD-9) and Anatomical Therapeutic Chemical (*ATC*). In this example to code the problems we used the ICD-9 coding, in this case, 427.31. To code the medication we used the ATC coding, in this case, B01AA03.

## 4. Discussion

The application of interoperability standards and open source software can bridge the gap between knowledge and clinical practice [7]. A CDS tool using an approach in which professionals share work using the social networks should reinforce this idea.

The development of decision support functionalities using regional infrastructure services based on standards communications and opensource software will result in components which may be replicated in other hospitals of the region. The development of this tool makes it possible to create a collaborative work environment for clinical decision-making amongst healthcare professionals participating in the assistance and care of multimorbidity patients.

This paper makes headway in relation to the challenges identified in the work of Wright et al. [25] about solidifying knowledge representation formats.

The acceptance of the platform by the healthcare professionals is one of the main factors related to the success of its implementation. Our professionals valued positively the items related to the SN, PU and PEU of the Clinical Wall. We observed a strong association between the IU of the Clinical Wall and the remaining variables, with the PEU having a moderately higher association compared to the PU, SN and FC. We did not find differences in the IU of the Clinical Wall between the groups of professionals,

```
let $UPPER :=
   for $CWE.1_LinkEHRVar_0  in (distinct-values(/ZCE_ZC1/PID/PID.3/CX.9/CWE.1))
   where matches($CWE.1_LinkEHRVar_0,$in)
   return
      <EXTRACT>
          <id_pat>{data($CWE.1_LinkEHRVar_0)}</id_pat>
          <vMR archetype_ID="HL7-vMR-vMR.Test.v1::at0000">
              <problems archetype_ID="HL7-vMR-vMR.Test.v1::at0001">
                  {
                   let $aux_1 :=
                      for $ZCE_ZC1_LinkEHRVar_0  in (/ZCE_ZC1)
                      for $PRB.3_LinkEHRVar_0  in ($ZCE_ZC1_LinkEHRVar_0/ZCE_ZC1.PATIENT_PROBLEMS/PRB/PRB.3)
                      for $CE.3_LinkEHRVar_0  in ($PRB.3_LinkEHRVar_0/CE.3)
                      for $CE.2_LinkEHRVar_0  in (ibimeFunction:if-empty($PRB.3_LinkEHRVar_0/CE.2,xs:QName("CE.2")))
                      for $CE.1_LinkEHRVar_0  in ($PRB.3_LinkEHRVar_0/CE.1)
                      where $ZCE_ZC1_LinkEHRVar_0/PID/PID.3/CX.9/CWE.1=$CWE.1_LinkEHRVar_0 and $CE.1_LinkEHRVar_0 and $CE.3_LinkEHRVar_0
                      return
                         <combo archetype_ID="HL7-vMR-vMR.Test.v1::at0002">
                             <problemsat0001__problemat0002__problemCodeat0004__code>{data($CE.1_LinkEHRVar_0)}
                             </problemsat0001__problemat0002__problemCodeat0004__code>
                             <problemsat0001__problemat0002__problemCodeat0004__codeSystem>{data($CE.3_LinkEHRVar_0)}
                             </problemsat0001__problemat0002__problemCodeat0004__codeSystem>
                             <problemsat0001__problemat0002__problemCodeat0004__displayName>{data($CE.2_LinkEHRVar_0)}
                             </problemsat0001__problemat0002__problemCodeat0004__displayName>
                         </combo>
                   for $combo_2  in ((ibimeFunction:distinct-deep($aux_1)))
                   where count(ibimeFunction:distinct-deep($aux_1))>=1
                   return
                         <problem archetype_ID="HL7-vMR-vMR.Test.v1::at0002" xsi:type="Problem">
                             <id archetype_ID="HL7-vMR-vMR.Test.v1::IILiteat" xsi:type="II_Lite">
                                 <root>NA</root>
                             </id>
                             <clinicalStatementType archetype_ID="HL7-vMR-vMR.Test.v1::CSLiteClinicalStatementTypeat"
                                xsi:type="CS_Lite_ClinicalStatementType">
                                 <code>NA</code>
                             </clinicalStatementType>
                             <problemCode archetype_ID="HL7-vMR-vMR.Test.v1::at0004"
                                codeSystem="{$combo_2/problemsat0001__problemat0002__problemCodeat0004__codeSystem}"
                                code="{$combo_2/problemsat0001__problemat0002__problemCodeat0004__code}" xsi:type="CD_Lite"
                                displayName="{$combo_2/problemsat0001__problemat0002__problemCodeat0004__displayName}">
                             </problemCode>
                             <problemStatus archetype_ID="HL7-vMR-vMR.Test.v1::CSLiteProblemStatusat" code="NA" xsi:type="CS_Lite_ProblemStatus">
                             </problemStatus>
                         </problem>
                  }
              </problems>
```

**Fig. 3.** xQuery to map problems and prescriptions from CCD to vMR.

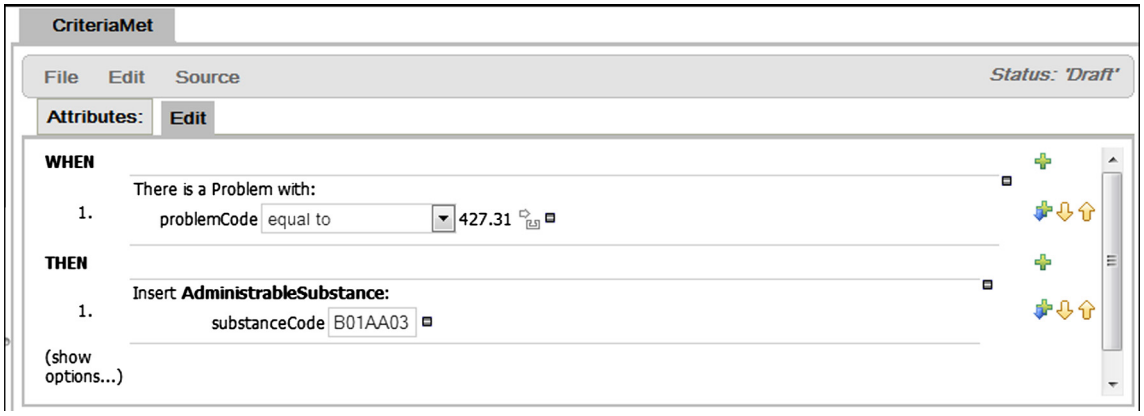


**Fig. 4.** Rule created using the Guvnor tool.

```
rule "CriteriaMet"
        dialect "mvel"
        when
                Problem( problemCode == "427.31" )
        then
                AdministrableSubstance fact0 = new AdministrableSubstance();
                fact0.setSubstanceCode( B01AA03 );
                insert(fact0 );
end
```

**Fig. 5.** Rule in text format (.drl).

but did between professionals from different healthcare centers. This could be due to the distance from CPC to the reference hospital, which is much longer than the distance from LPPC to the reference hospital. Clinicians from CPC center could easily perceive the benefits for patients in using the SCP for better management of appointments and agreed decisions among diagnostic tests and prescriptions.

The comparison between clinicians intended use stated in the questionnaire and the actual use made by health professionals there is a poor relationship as only 10 of the 40 professionals who completed the acceptance questionnaire used the Clinical Wall. However, we believe that the developments proposed for the tool will increase participation and use of these professionals. The aim of incorporating exchange utilities to support clinical decision-making is to improve the assistance and care of multimorbidity patients. Furthermore, it will be able to obtain a higher level of consensus between professionals. In the same way, we are working on the design of a future study to make a rigorous assessment of the concordance between the decisions taken by the professional and the tool, the adherence of professionals to the tool, the impact on the consumption of resources, patient health outcomes, etc. We expect that the evaluation of the impact of DSS on clinical practice will help to increase the promotion of DSS standards and tools in large health infrastructures.

After finishing the development of the second stage with the incorporation of the decision support functionalities, it will be possible to increase the safety of patients verifying that clinicians review possible interactions among the medications and problems. The combination of DSS with Social network technologies will allow rapid feedback about the usefulness of the defined rules. This will allow the definition of common governance for rules that will be enriched by the real experience of clinical practice provided by all the health professionals involved in patient care.

Although medication list and problem interaction rules are based on clinical evidence accepted in the literature, it is expected that form their application with of a large population of multimorbidity patients will raise exceptions to the rules. The incorporation of a layer for rules management will increase the flexibility for incorporating the knowledge based required for complex decisions.

The design of our platform using rules has many benefits, but it also makes the developments more complex and extensive, having to transform the format of the information required from our electronic history systems to vMR so that it can be used with OpenCDS. With OpenCDS already integrated with the SCP, the future work will be focused on increasing the number of rules modeled to be able to provide additional support to the health professionals.

## 5. Conclusions

Clinical Wall has been developed to allow communication and coordination between the healthcare professionals involved in multimorbidity patient care. Agreed decisions were about coordination for changes in appointments, patient conditions, diagnosis tests, and prescription changes and renewal. As a consequence, it is perceived that the decisions made had a high impact on patient safety and continuity of care.

The application of interoperability standards and open source software can bridge the gap between knowledge and clinical practice, while enabling interoperability and scalability. Open source with the social network encourages adoption and facilitates collaboration.

Although the results obtained for use indicators are still not as high as it was expected, based on the promising results obtained in the acceptance questionnaire of SMP, we expect that the new CDS tools will increase the use by the health professionals. A second study will be performed once the full number of rules will be implemented to obtain additional information about the impact on patient care from the SCP.

## Acknowledgments

This study has been carried out within the framework of the PITeS project "Methods and tools for design and implementation of Telemedicine and eHealth for the care of chronic patients", dossier number PI09/90518, financed by the Spanish Ministry of Science and Innovation.

We thank all who participated in this study, and particularly those who directly or indirectly contributed to the publication of this article from LPPC Center, CPC Center and Internal Medicine Department of VRUH. We thank the Network for Innovation in Medical Technologies and Health (Red ITEMAS in Spanish), dossier number RD09/0077/00025, promoted by the Carlos III Health Institute.

## References

[1] Kamel Boulos MN, Wheeler S. The emerging Web 2.0 social software: an enabling suite of sociable technologies in health and health care education. Health Info Libr J 2007;24(1):2–23.
[2] Gupta S, Wan FT, Newton D, Bhattacharyya OK, Chignell MH, Straus SE. WikiBuild: a new online collaboration process for multistakeholder tool development and consensus building. J Med Internet Res 2011;13(4):e108.
[3] Schweitzer J, Hannan A, Coren J. The role of social networking web sites in influencing residency decisions. J Am Osteopath Assoc 2012;112(10):673–9.
[4] Nijland N, van Gemert-Pijnen JE, Kelders SM, Brandenburg BJ, Seydel ER. Factors influencing the use of a Web-based application for supporting the self-care of patients with type 2 diabetes: a longitudinal study. J Med Internet Res 2011;13(3):e71.
[5] Wylie SA, Hassan A, Krull EG, Pikcilingis AB, Corliss HL, Woods ER, et al. Assessing and referring adolescents' health-related social problems: qualitative evaluation of a novel web-based approach. J Telemed Telecare 2012.
[6] Garg AX, Adhikari NK, McDonald H, Rosas-Arellano MP, Devereaux PJ, Beyene J, et al. Effects of computerized clinical decision support systems on practitioner performance and patient outcomes: a systematic review. JAMA 2005;293(10):1223–38.
[7] Kawamoto K, Houlihan CA, Balas EA, Lobach DF. Improving clinical practice using clinical decision support systems: a systematic review of trials to identify features critical to success. BMJ 2005;330(7494):765.
[8] Osheroff JA, Teich JM, Middleton B, Steen EB, Wright A, Detmer DE. A roadmap for national action on clinical decision support. J Am Med Inform Assoc 2007;14(2):141–1415.
[9] World Health Organization. World health statistics. Geneva; 2008.
[10] Bernabeu-Wittel M, Baron-Franco B, Murcia-Zaragoza J, Fuertes-Martin A, Ramos-Cantos C, Fernandez-Moyano A, et al. A multi-institutional, hospital-based assessment of clinical, functional, sociofamilial and health-care characteristics of polypathological patients (PP). Arch Gerontol Geriatr 2011;53(3):284–91.
[11] Garcia-Morillo JS, Bernabeu-Wittel M, Ollero-Baturone M, Aguilar-Guisad M, Ramirez-Duque N, Gonzalez de la Puente MA, et al. Incidence and clinical features of patients with comorbidity attended in internal medicine areas. Med Clin (Barc) 2005;125(1):5–9.
[12] Ramirez-Duque N, Ollero-Baturone M, Bernabeu-Wittel M, Rincon-Gomez M, Ortiz-Camunez MA, Garcia-Morillo S. Clinical, functional, mental and sociofamiliar features in pluripathological patients. One-year prospective study in Primary Health Care. Rev Clin Esp 2008;208(1):4–11.
[13] Ollero-Baturone M, Alvarez M, Barón-Franco B, Bernabeu-Wittel M, Codina A, Fernández-Moyano A et al. Care for polypathological patients. Integrated care process. 2nd ed. Seville; 2007.
[14] Davis F. Perceived usefulness, perceived ease of use and user acceptance of information technology. MIS Q 1989;13(3):319–39.
[15] Holden RJ, Karsh BT. The technology acceptance model: its past and its future in health care. J Biomed Inform 2010;43(1):159–72.
[16] Bernabeu-Wittel M, Ollero-Baturone M, Moreno-Gavino L, Baron-Franco B, Fuertes A, Murcia-Zaragoza J, et al. Development of a new predictive model for polypathological patients. The PROFUND index. Eur J Intern Med 2011;22(3):311–7.
[17] Beers MH, Ouslander JG, Rollingher I, Reuben DB, Brooks J, Beck JC. Explicit criteria for determining inappropriate medication use in nursing home residents. UCLA division of geriatric medicine. Arch Intern Med 1991;151(9):1825–32.
[18] Beers MH. Explicit criteria for determining potentially inappropriate medication use by the elderly. An update. Arch Intern Med 1997;157(14):1531–6.
[19] Fick DM, Cooper JW, Wade WE, Waller JL, Maclean JR, Beers MH. Updating the Beers criteria for potentially inappropriate medication use in older adults: results of a US consensus panel of experts. Arch Intern Med 2003;163(22):2716–24.
[20] Gallagher P, Ryan C, Byrne S, Kennedy J, O'Mahony D. STOPP (Screening Tool of Older Person's Prescriptions) and START (Screening Tool to Alert doctors to Right Treatment). Consensus validation. Int J Clin Pharmacol Ther 2008;46(2):72–83.
[21] Open CDS. OpenCDS. 2012. <http://www.opencds.org>.
[22] Health Level Seven. Virtual Medical Record (vMR) for Clinical decision support – domain analysis model. Release 1. 2011. <http://www.hl7.org/implement/standards/product_brief.cfm?product_id=270>.
[23] JBoss. Drools-Guvnor. 2012. <http://www.jboss.org/drools/drools-guvnor>.
[24] Maldonado JA, Moner D, Bosca D, Fernandez-Breis JT, Angulo C, Robles M. LinkEHR-Ed: a multi-reference model archetype editor based on formal semantics. Int J Med Inform 2009;78(8):559–70.
[25] Wright A, Bates DW, Middleton B, Hongsermeier T, Kashyap V, Thomas SM, et al. Creating and sharing clinical decision support content with Web 2.0: issues and examples. J Biomed Inform 2009;42(2):334–46.